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# **Development of Graphical User Interface Status Board and Control Rod Calibration Software in Python for the Oregon State TRIGA Reactor**

**Griffen Latimer**

**Monday, October 29<sup>th</sup>, 2018**



**Oregon State University**  
College of Engineering

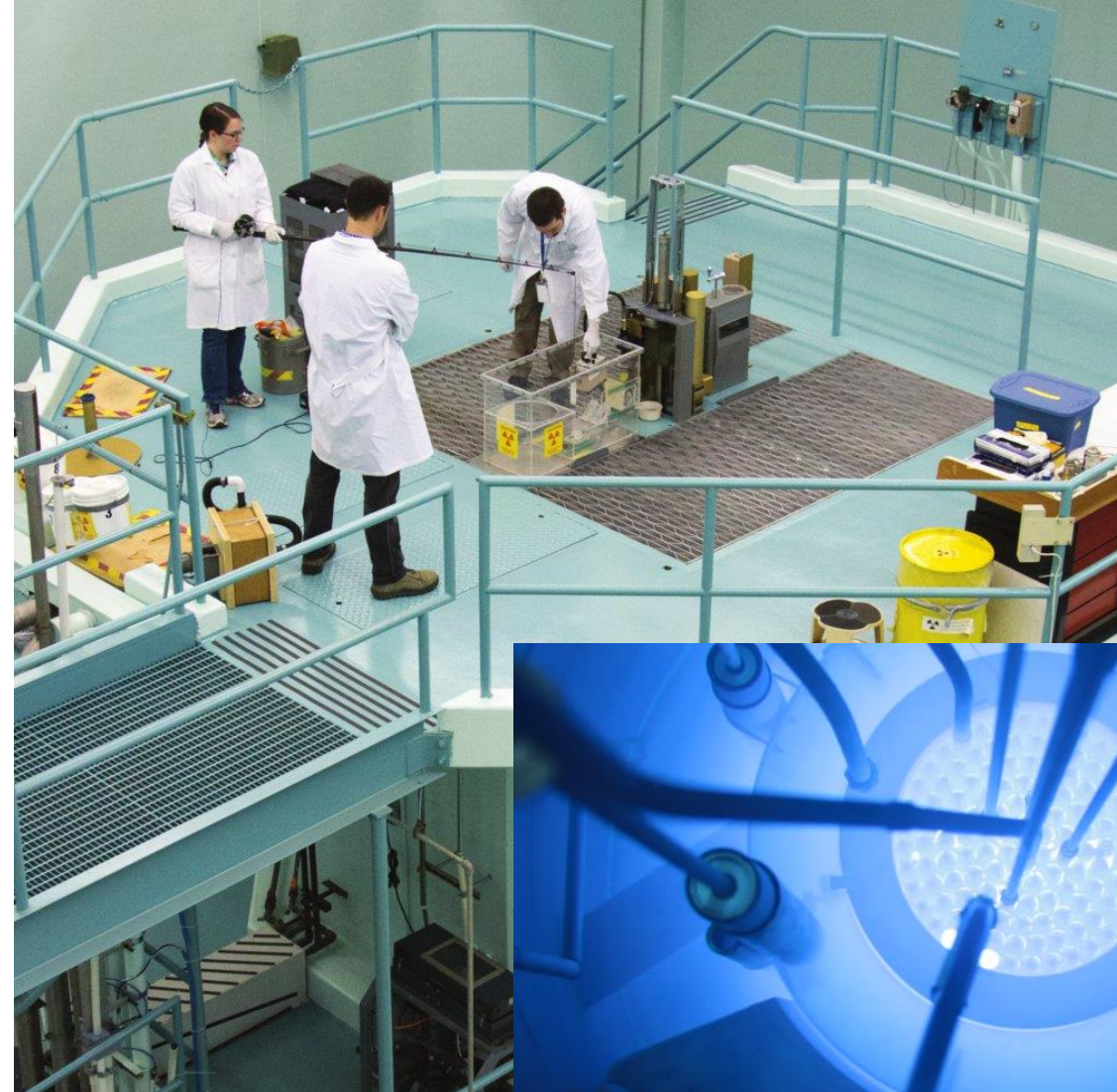
# **Part I: Status Board**

# Oregon State TRIGA Reactor



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- 1 MW<sub>th</sub> MkII TRIGA
- In the previous year operated 1579 hours, producing 60 MWd
- 1,143 samples irradiated in-pile
- Numerous customers, irradiation facilities

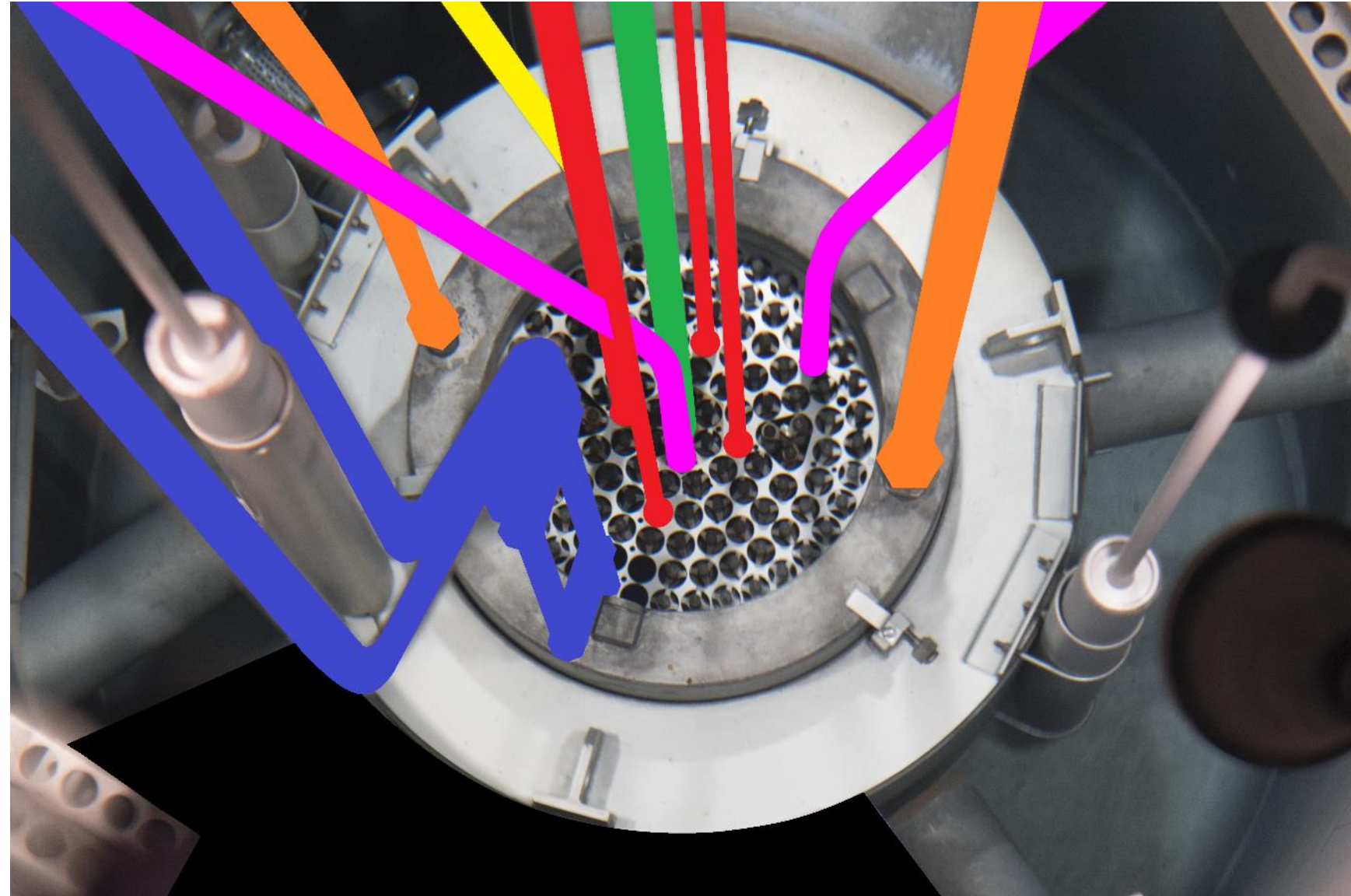


# Oregon State TRIGA Reactor



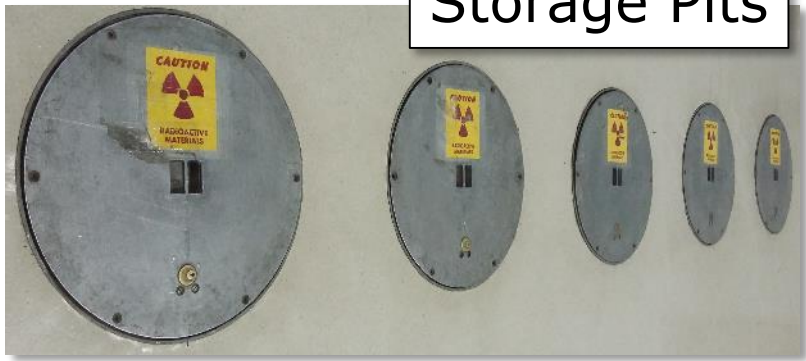
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- CLICIT/CLOCIT
- ICIT
- Control Rods
- Rotating Rack
- Thermal Column
- Central Thimble
- Rabbit



# Sample Storage

Storage Pits



Antimony Rack



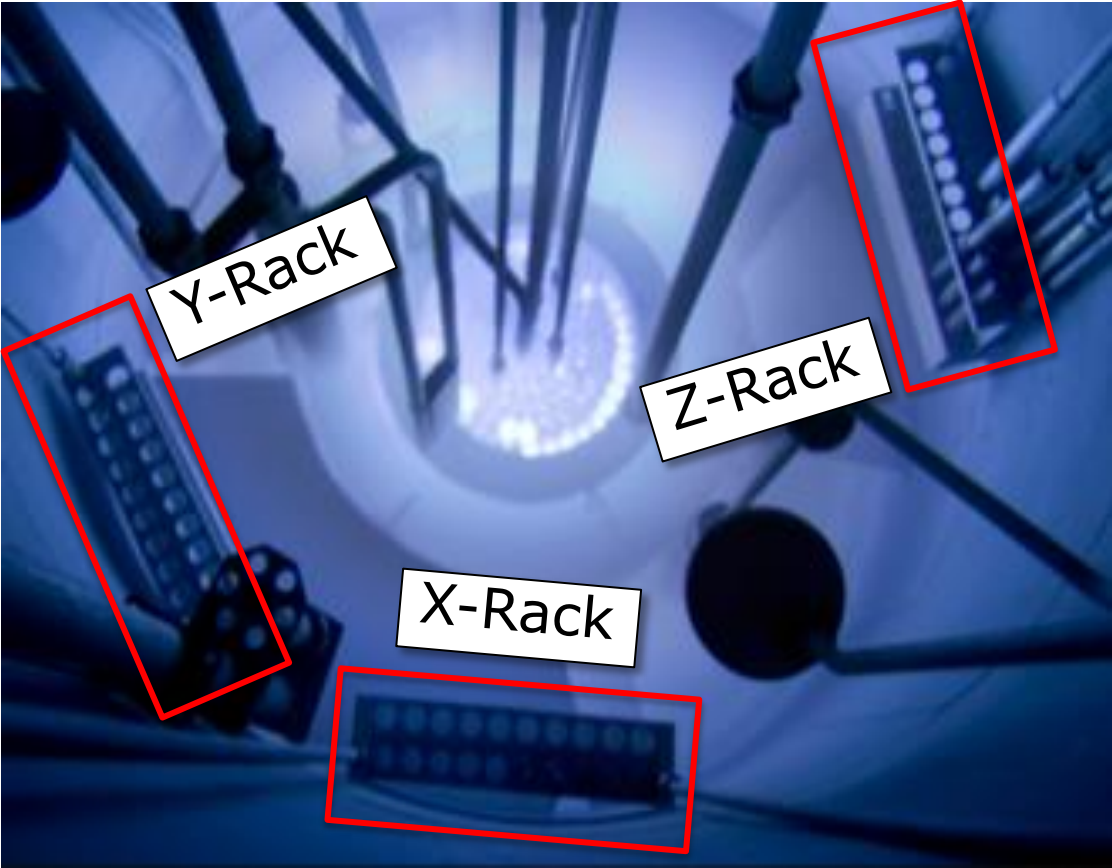
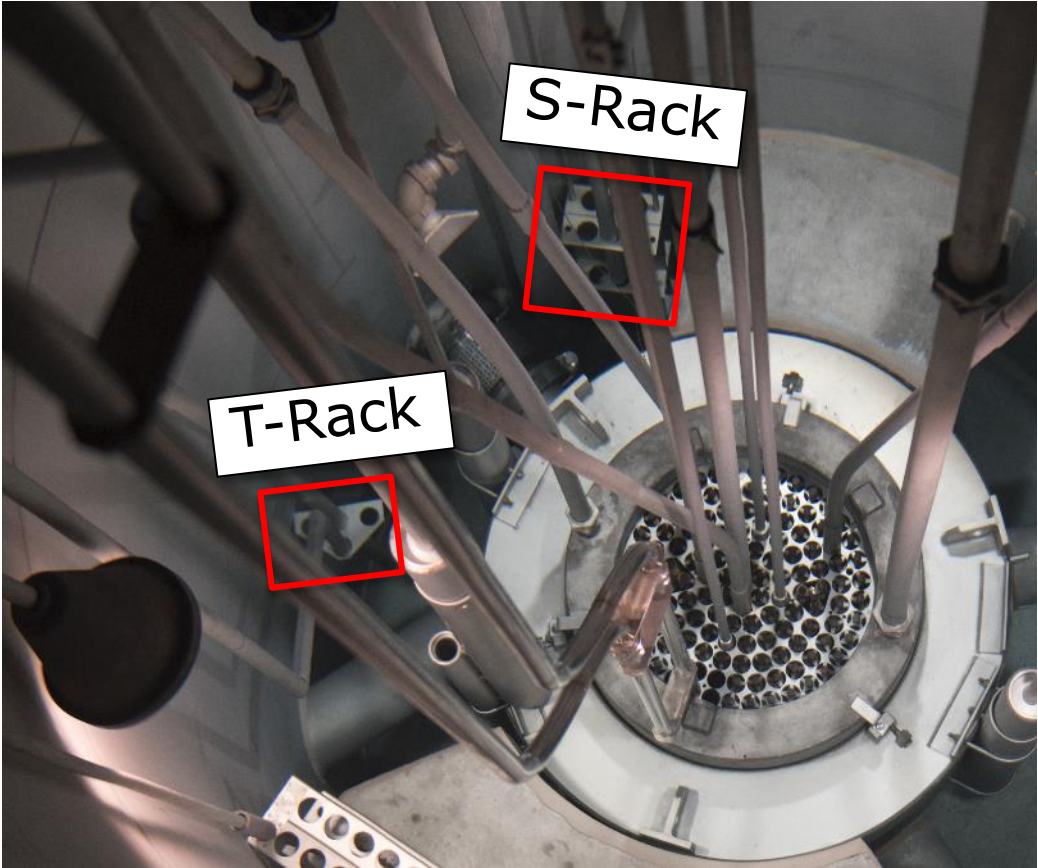
Reactor Top Cave



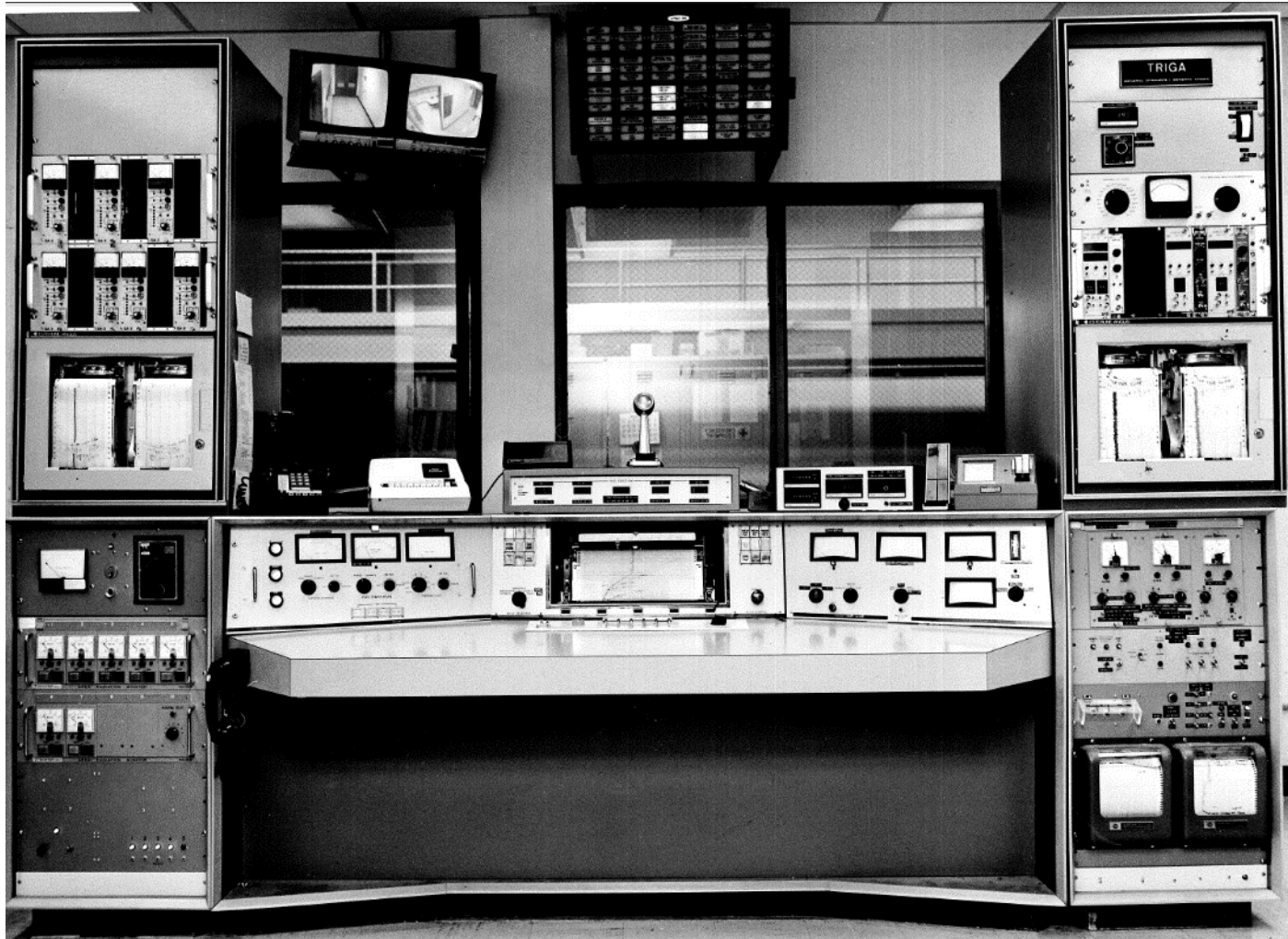
Thermal Column



# Tank Storage



# Status Board 1



# Status Board 2

**Sample Storage**

Rx Top Cave

18-022/023/024  
18-039  
18-035  
18-038  
18-033  
18-034  
18-049  
18-051  
18-050

**S-Rack**

Position 1 Name: Empty IR #: none  
Position 2 Name: Empty IR #: none  
Position 3 Name: Empty IR #: none  
Position 4 Name: CLICIT #4 IR #:   
Position 5 Name: Empty IR #: none  
Position 6 Name: ICIT2 IR #: Empty

**T-Rack**

Position 1 Name: CLICIT #1 IR #: Empty  
Position 2 Name: EMPTY IR #:   
Position 3 Name: EMPTY IR #:

**Antimony Rack**

Position 1 UPPER Small IR #: none LOWER Large IR #:   
Position 3 UPPER Large IR #: X factor LOWER Large IR #: X-Factor 1  
Position 5 UPPER EMPTY IR #:   
Position 6 LOWER Small IR #:

**Z\_Rack**

Position 1 Reflector LD. RE-24  
Position 2 Reflector LD. RE-34  
Position 3 Reflector LD. RE-19  
Position 4 Reflector LD. RE-08  
Position 5 Reflector LD. RE-39  
Position 6 Reflector LD. RE-29  
Position 7 Empty  
Position 8 Empty  
Position 9 Empty  
Position 10 Empty  
Position 13 Empty  
Position 14 Empty  
Position 15 Empty  
Position 16 Empty  
Position 17 Empty  
Position 18 Empty  
Position 19 Empty  
Position 20 Empty

**CORE STATUS**

**DATE**      **ITEM**      **ACTION**

10/07/2008	66 LEU elements	Initial criticality of LEU core
10/14/2008	90 LEU elements	LEU Core #1
03/25/2010	Safe Channel Chamber	Replaced CIC with UIC
11/15/2011	Fission Chamber	Replaced FC
04/01/2013	Rabbit Terminus	Rplcd AI terminus w/ TVSS
11/01/2013	Reflector outage	New reflector installed
11/10/2016	Safe Channel Chamber	Replaced UIC
12/18/2016	Safe Channel Chamber	Replaced UIC

**THERMAL COLUMN**

18-043

**ROTATING RACK**

**NOTES**

Control Rod Adapter Holes: D3, D8, E16, E21



# Status Board 2



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# Python and TkInter

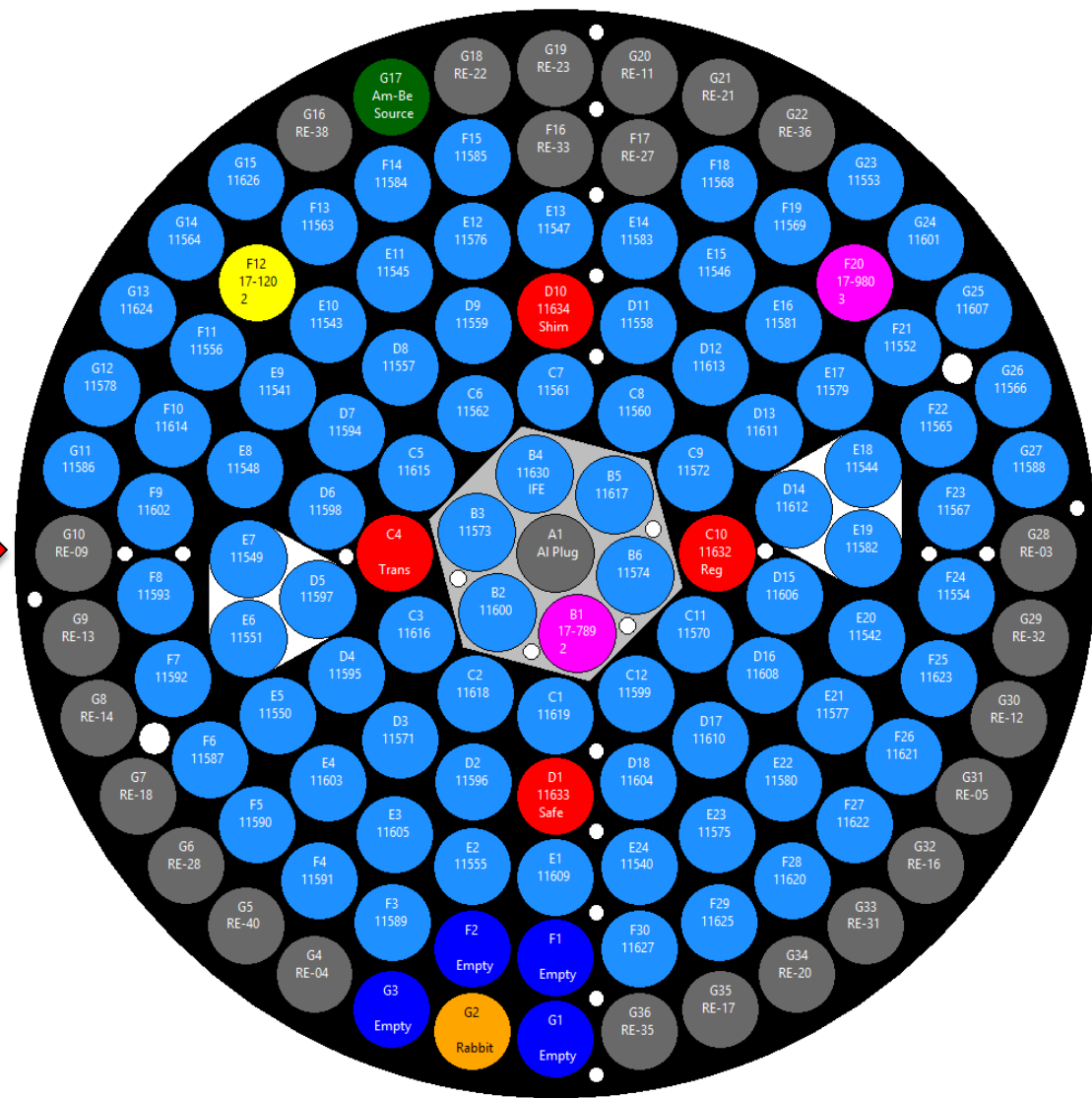
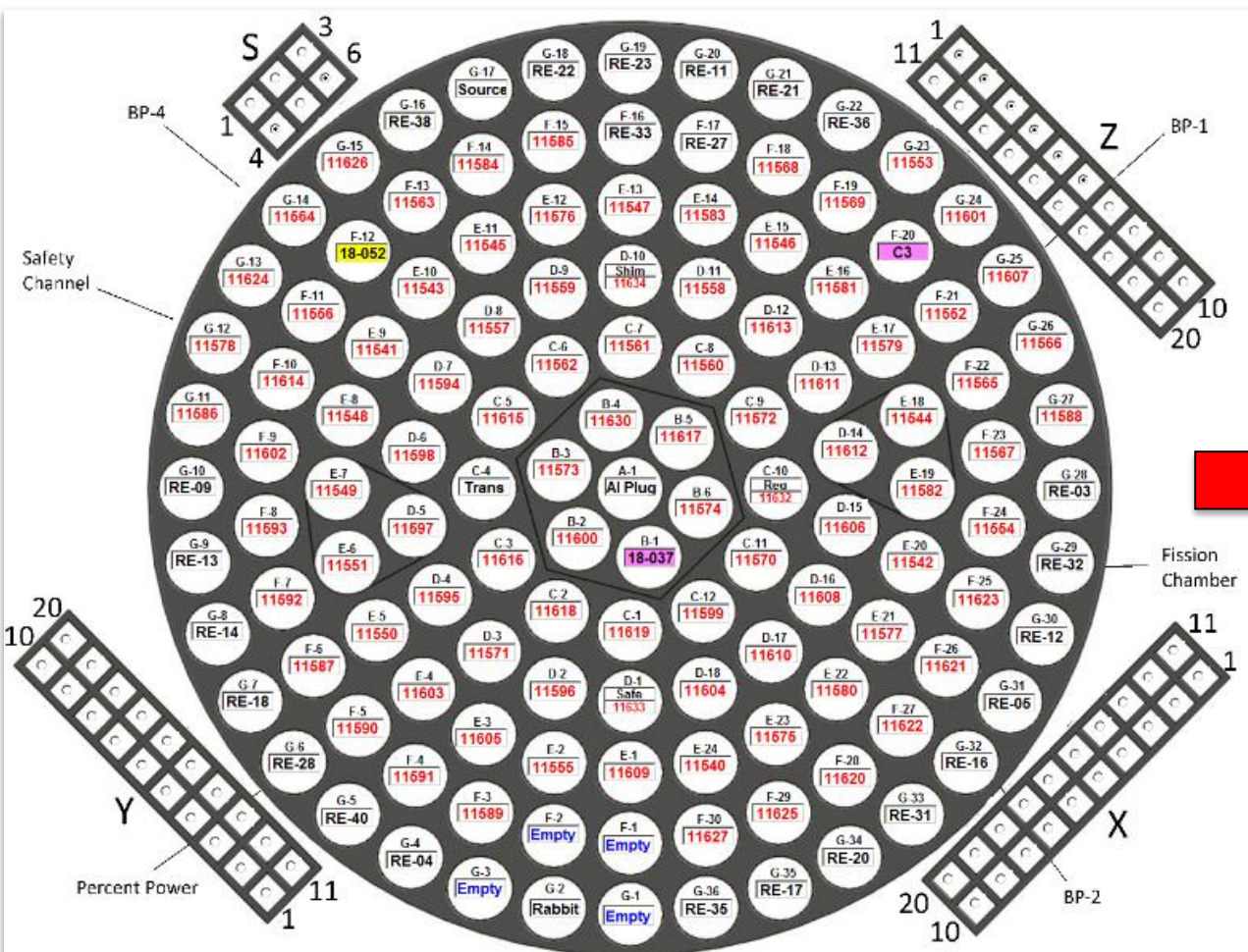


- Free
- Large user base
- Modules added as needed
- Object oriented



```
1 from Tkinter import *
2 import numpy as np
3 import Pmw
4 import csv
```

# Status Board 3 – Core Layout



# Status Board 3



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SAVE

Irradiation Facilities

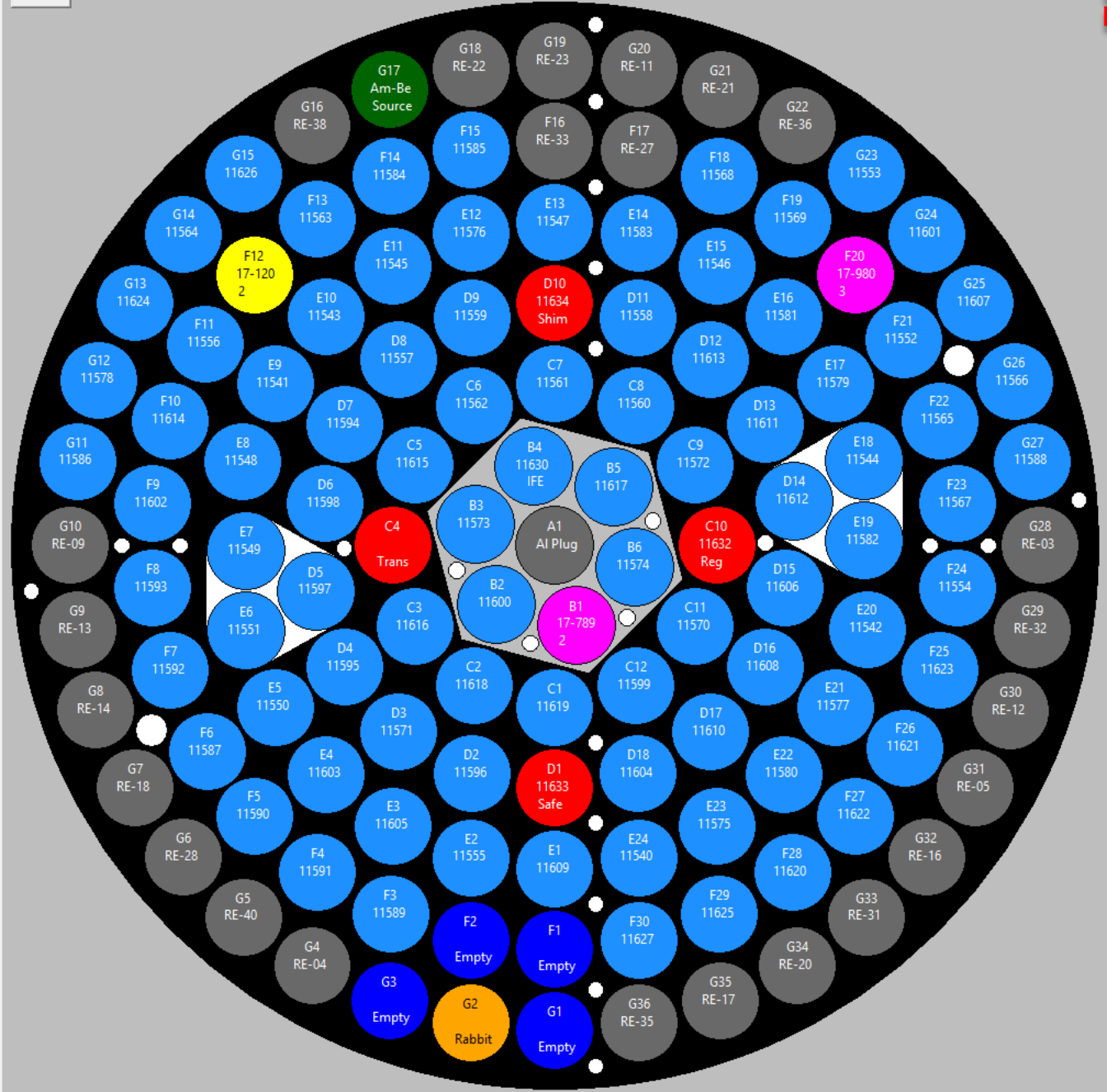
/ S / A Racks

X / Y / Z Racks

Rx Top Cave & Storage Pits

Core Status & Notes

Edit Core Map



B1 CLICIT

**B-1 CLICIT #**  **IR #**

F20 CLICIT

**F-20 CLICIT #**  **IR #**

F12 ICIT

**F-12 ICIT #**  **IR #**

Rotating Rack

**LS 1 - IR #**  **LS 2 - IR #**

**LS 3 - IR #**  **LS 4 - IR #**

**LS 5 - IR #**  **LS 6 - IR #**

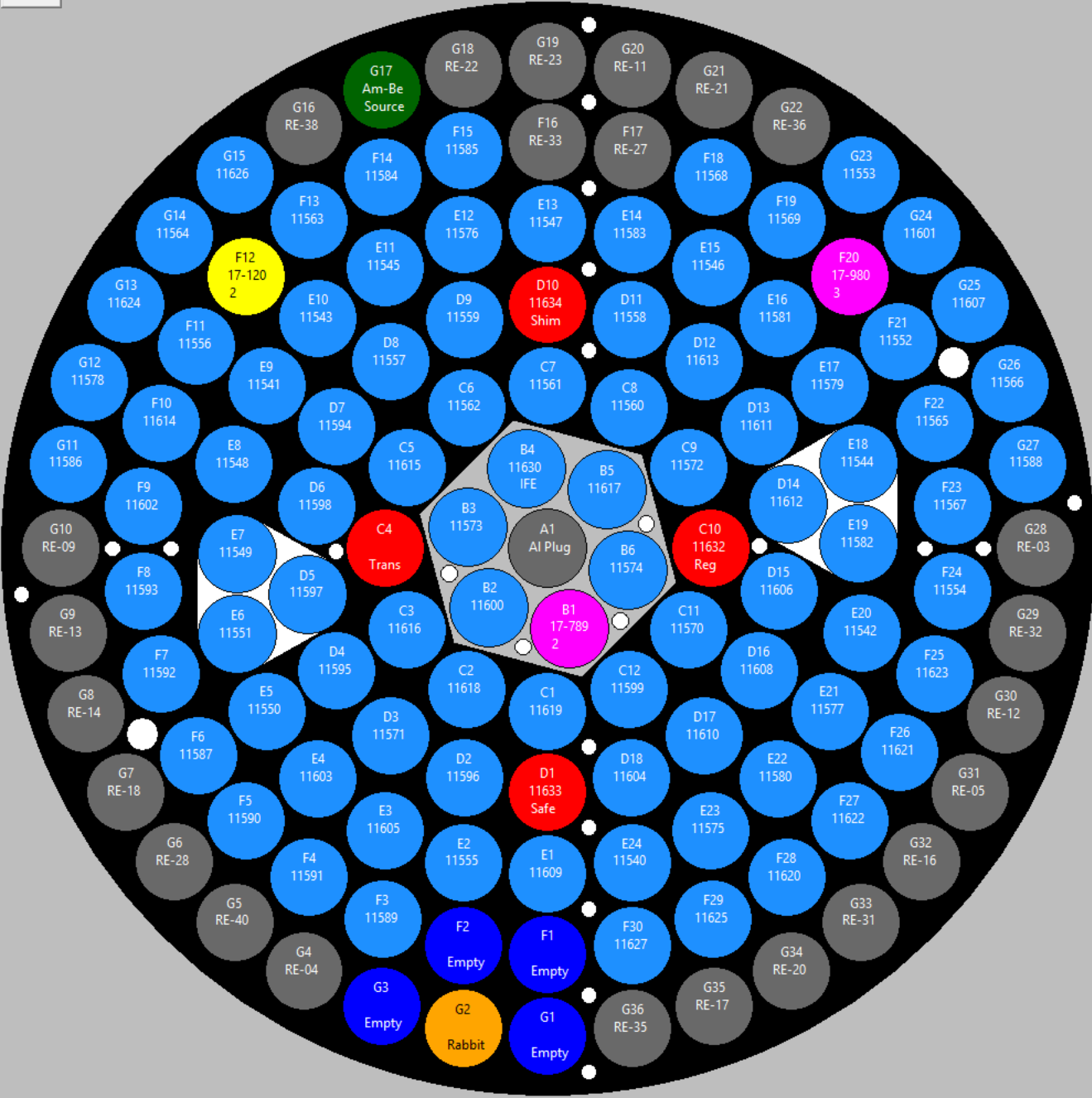
Thermal Column

**TC 1 - IR #**  **TC 2 - IR #**

**TC 3 - IR #**  **TC 4 - IR #**

**TC 5 - IR #**  **TC 6 - IR #**

SAVE



T Rack

T1:   IR #

T2:   IR #

T3:   IR #

S Rack

S1:   IR #

S2:   IR #

S3:   IR #

S4:   IR #

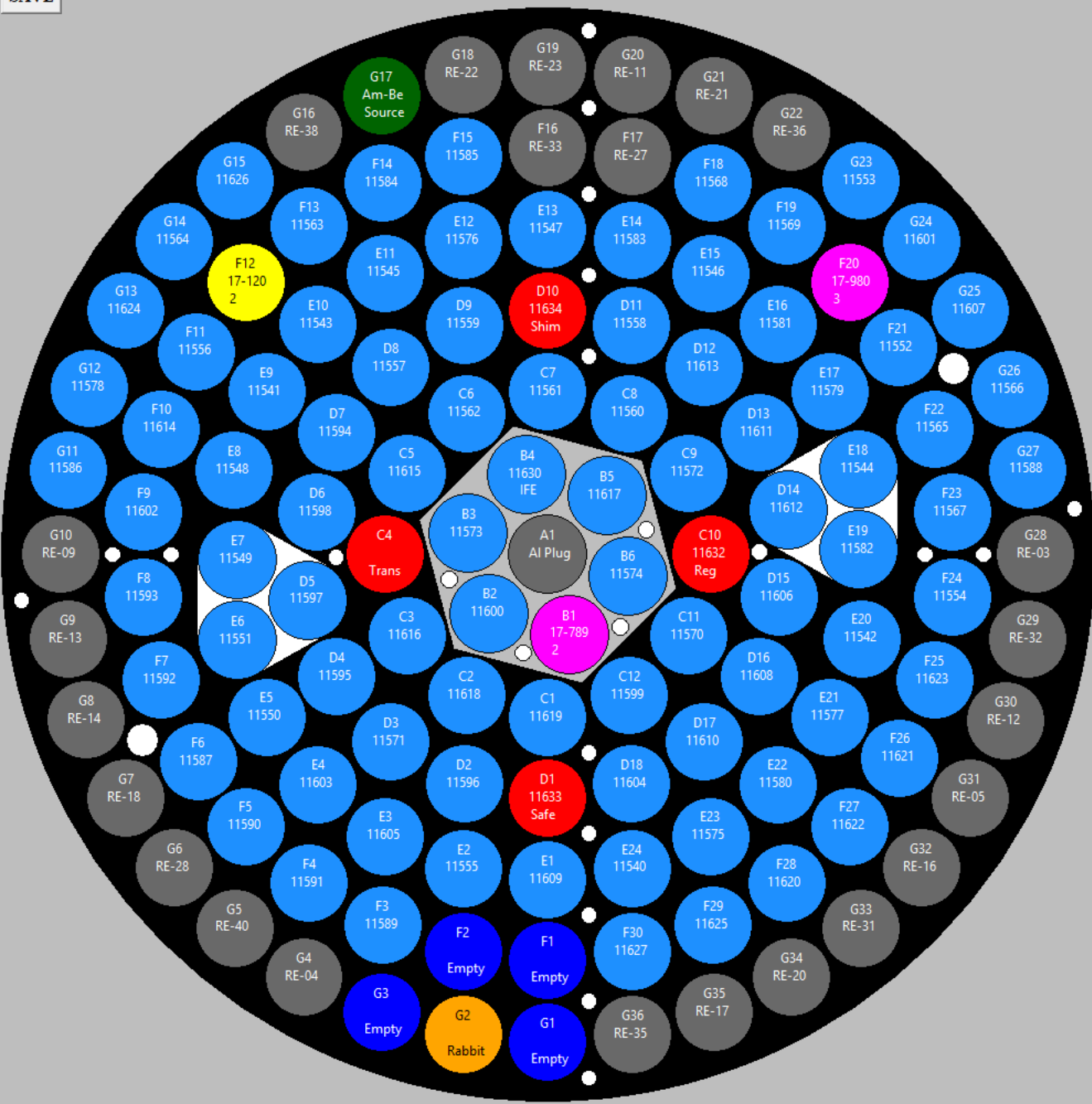
S5:   IR #

S6:   IR #

Antimony Rack

A1	A2	A3
Upper <input type="text" value="Large"/> IR # <input type="text" value="17-906"/>	Upper <input type="text" value="Empty"/> IR # <input type="text"/>	Upper <input type="text" value="Empty"/> IR # <input type="text"/>
Lower <input type="text" value="Empty"/> IR # <input type="text"/>	Lower <input type="text" value="Empty"/> IR # <input type="text"/>	Lower <input type="text" value="Empty"/> IR # <input type="text"/>
A4	A5	A6
Upper <input type="text" value="Empty"/> IR # <input type="text"/>	Upper <input type="text" value="Empty"/> IR # <input type="text"/>	Upper <input type="text" value="Empty"/> IR # <input type="text"/>
Lower <input type="text" value="Empty"/> IR # <input type="text"/>	Lower <input type="text" value="Empty"/> IR # <input type="text"/>	Lower <input type="text" value="Empty"/> IR # <input type="text"/>

SAVE



X Rack

X1:	Empty	ID:	
X2:	Fuel	ID:	
X3:	Ref	ID:	
X4:	CR	ID:	
X5:	CLICIT	ID:	
X6:	ICIT	ID:	
X7:	Rabbit	ID:	
X8:	Empty	ID:	
X9:	AI	ID:	
X10:	Source	ID:	
X11:	Empty	ID:	
X12:	Empty	ID:	
X13:	Empty	ID:	
X14:	Empty	ID:	
X15:	Empty	ID:	
X16:	Empty	ID:	
X17:	Empty	ID:	
X18:	Empty	ID:	
X19:	Empty	ID:	
X20:	Empty	ID:	

Y Rack

Y1:	Empty	ID:	
Y2:	Empty	ID:	
Y3:	Empty	ID:	
Y4:	Empty	ID:	
Y5:	Empty	ID:	
Y6:	Empty	ID:	
Y7:	Empty	ID:	
Y8:	Empty	ID:	
Y9:	Empty	ID:	
Y10:	Empty	ID:	
Y11:	Empty	ID:	
Y12:	Empty	ID:	
Y13:	Empty	ID:	
Y14:	Empty	ID:	
Y15:	Empty	ID:	
Y16:	Empty	ID:	
Y17:	Empty	ID:	
Y18:	Empty	ID:	
Y19:	Empty	ID:	
Y20:	Empty	ID:	

Z Rack

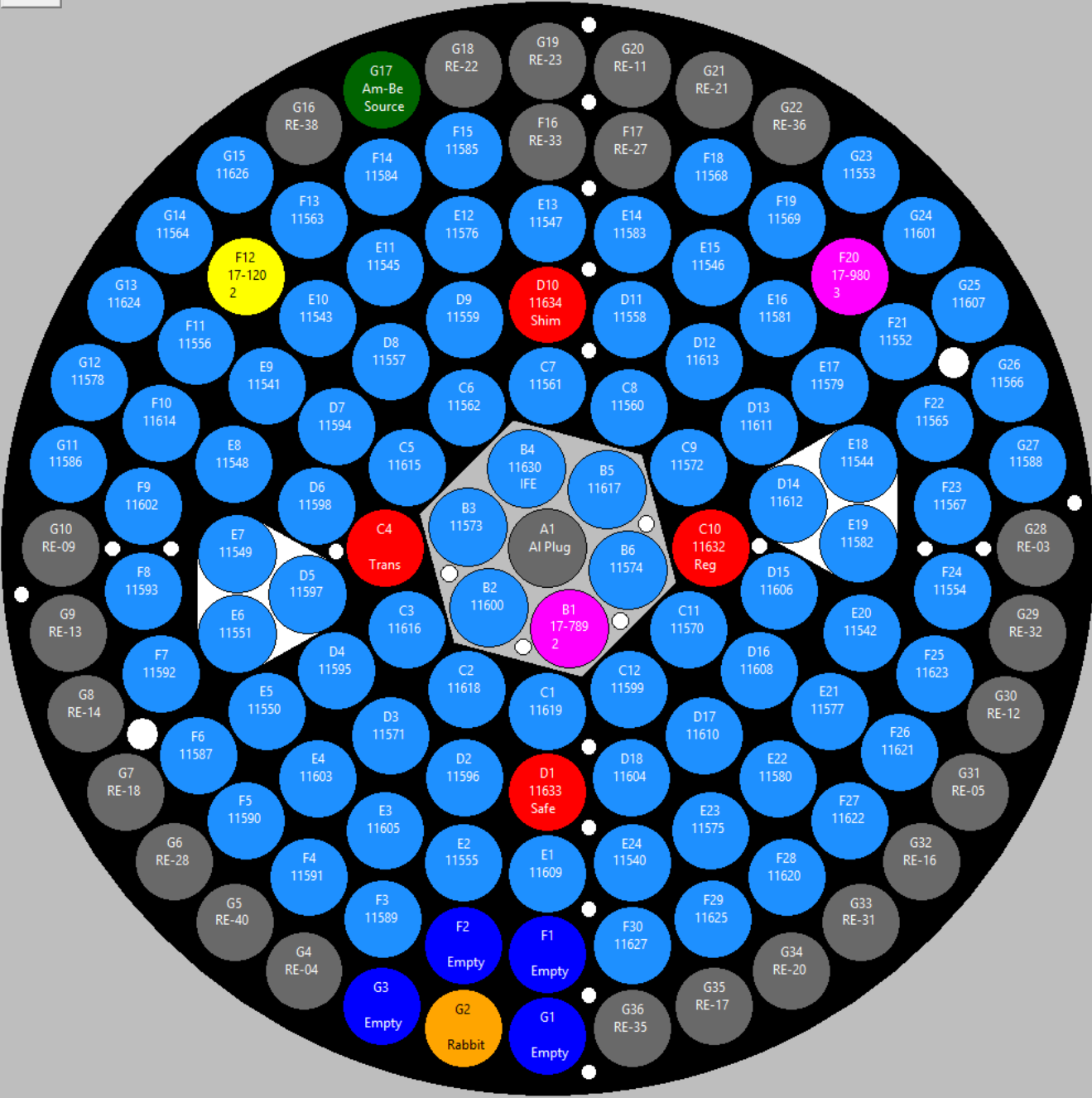
Z1:	Empty	ID:	
Z2:	Empty	ID:	
Z3:	Empty	ID:	
Z4:	Empty	ID:	
Z5:	Empty	ID:	
Z6:	Empty	ID:	
Z7:	Empty	ID:	
Z8:	Empty	ID:	
Z9:	Empty	ID:	
Z10:	Empty	ID:	
Z11:	Empty	ID:	
Z12:	Empty	ID:	
Z13:	Empty	ID:	
Z14:	Empty	ID:	
Z15:	Empty	ID:	
Z16:	Empty	ID:	
Z17:	Empty	ID:	
Z18:	Empty	ID:	
Z19:	Empty	ID:	
Z20:	Empty	ID:	







SAVE



Irradiation Facilities	T / S / A Racks		X / Y / Z Racks		Rx Top Cave & Storage Pits	Core Status & Note	Edit Core Map
	Facility	Component	ID	Notes			
A1	AI	Plug	D: AI Plug		D14	Fuel	ID: 11612
B1	CLICIT		D: 17-789 2		D15	Fuel	ID: 11606
B2	Fuel		D: 11600		D16	Fuel	ID: 11608
B3	Fuel		D: 11573		D17	Fuel	ID: 11610
B4	Ref	CR	D: 11630	IFE	D18	Fuel	ID: 11604
B5	CLICIT	ICIT	D: 11617		E1	Fuel	ID: 11609
B6	Rabbit	Empty	D: 11574		E2	Fuel	ID: 11555
C1	AI	Source	D: 11619		E3	Fuel	ID: 11605
C2			D: 11618		E4	Fuel	ID: 11603
C3	Fuel		ID: 11616		E5	Fuel	ID: 11550
C4	CR		ID:	Trans	E6	Fuel	ID: 11551
C5	Fuel		ID: 11615		E7	Fuel	ID: 11549
C6	Fuel		ID: 11562		E8	Fuel	ID: 11548
C7	Fuel		ID: 11561		E9	Fuel	ID: 11541
C8	Fuel		ID: 11560		E10	Fuel	ID: 11543
C9	Fuel		ID: 11572		E11	Fuel	ID: 11545
C10	CR		ID: 11632	Reg	E12	Fuel	ID: 11576
C11	Fuel		ID: 11570		E13	Fuel	ID: 11547
C12	Fuel		ID: 11599		E14	Fuel	ID: 11583
D1	CR		ID: 11633	Safe	E15	Fuel	ID: 11546
D2	Fuel		ID: 11596		E16	Fuel	ID: 11581
D3	Fuel		ID: 11571		E17	Fuel	ID: 11579
D4	Fuel		ID: 11595		E18	Fuel	ID: 11544
D5	Fuel		ID: 11597		E19	Fuel	ID: 11582
D6	Fuel		ID: 11598		E20	Fuel	ID: 11542
D7	Fuel		ID: 11594		E21	Fuel	ID: 11577
D8	Fuel		ID: 11557		E22	Fuel	ID: 11580
D9	Fuel		ID: 11559		E23	Fuel	ID: 11575
D10	CR		ID: 11634	Shim	E24	Fuel	ID: 11540
D11	Fuel		ID: 11558		F1	Empty	ID:
D12	Fuel		ID: 11613		F2	Empty	ID:
D13	Fuel		ID: 11611		F3	Fuel	ID: 11589
F4	Fuel		ID: 11591		G6	Ref	ID: RE-28
F5	Fuel		ID: 11590		G7	Ref	ID: RE-18
F6	Fuel		ID: 11587		G8	Ref	ID: RE-14
F7	Fuel		ID: 11592		G9	Ref	ID: RE-13
F8	Fuel		ID: 11593		G10	Ref	ID: RE-09
F9	Fuel		ID: 11602		G11	Fuel	ID: 11586
F10	Fuel		ID: 11614		G12	Fuel	ID: 11578
F11	Fuel		ID: 11556		G13	Fuel	ID: 11624
F12	ICIT		ID: 17-120 2		G14	Fuel	ID: 11564
F13	Fuel		ID: 11563		G15	Fuel	ID: 11626
F14	Fuel		ID: 11584		G16	Ref	ID: RE-38
F15	Fuel		ID: 11585		G17	Source	ID: Am-Be Source
F16	Ref		ID: RE-33		G18	Ref	ID: RE-22
F17	Ref		ID: RE-27		G19	Ref	ID: RE-23
F18	Fuel		ID: 11568		G20	Ref	ID: RE-11
F19	Fuel		ID: 11569		G21	Ref	ID: RE-21
F20	CLICIT		ID: 17-980 3		G22	Ref	ID: RE-36
F21	Fuel		ID: 11552		G23	Fuel	ID: 11553
F22	Fuel		ID: 11565		G24	Fuel	ID: 11601
F23	Fuel		ID: 11567		G25	Fuel	ID: 11607
F24	Fuel		ID: 11554		G26	Fuel	ID: 11566
F25	Fuel		ID: 11623		G27	Fuel	ID: 11588
F26	Fuel		ID: 11621		G28	Ref	ID: RE-03
F27	Fuel		ID: 11622		G29	Ref	ID: RE-32
F28	Fuel		ID: 11620		G30	Ref	ID: RE-12
F29	Fuel		ID: 11625		G31	Ref	ID: RE-05
F30	Fuel		ID: 11627		G32	Ref	ID: RE-16
G1	Empty		ID:	Empty	G33	Ref	ID: RE-31
G2	Rabbit		ID:	Rabbit	G34	Ref	ID: RE-20
G3	Empty		ID:	Empty	G35	Ref	ID: RE-17
G4	Ref		ID: RE-04		G36	Ref	ID: RE-35

# Status Board File Details



- Framework in .py file
- Data saved in .csv file
- Runs on Python 2.7
- 560 lines of code (old status board was 10,000+ lines in separate files)

	A	B	C	D
1	A1	AI	AI Plug	
2	B1	CLICIT	17-789	2
3	B2	Fuel	11600	
4	B3	Fuel	11573	
5	B4	Fuel	11630	IFE
6	B5	Fuel	11617	
7	B6	Fuel	11574	
8	C1	Fuel	11619	
9	C2	Fuel	11618	
10	C3	Fuel	11616	
11	C4	CR		Trans
12	C5	Fuel	11615	
13	C6	Fuel	11562	
14	C7	Fuel	11561	
15	C8	Fuel	11560	
16	C9	Fuel	11572	
17	C10	CR	11632	Reg
18	C11	Fuel	11570	
19	C12	Fuel	11599	
20	D1	CR	11633	Safe

python (32 bit) (2)	0%	7.0 MB	0 MB/s	0 Mbps	0%
python (32 bit)	0%	6.3 MB	0 MB/s	0 Mbps	0%
Console Window Host	0%	0.7 MB	0 MB/s	0 Mbps	0%

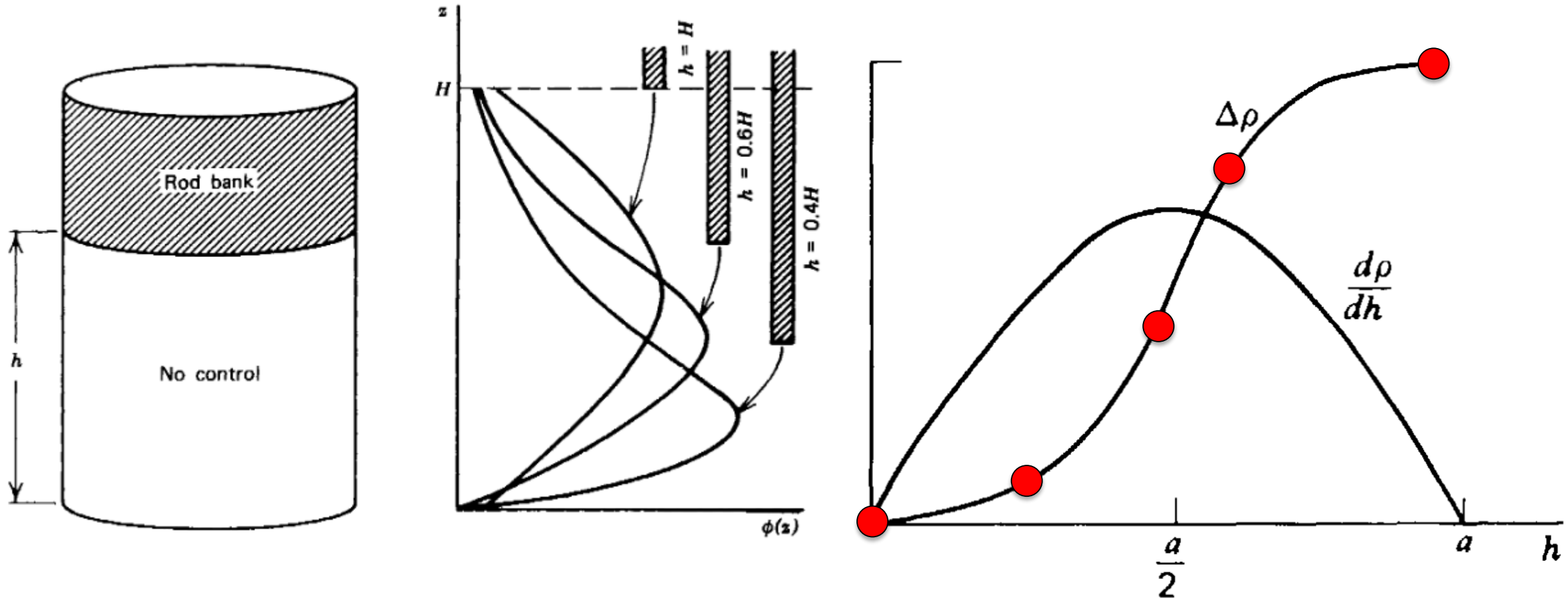
OSTR_Status_Board	11/27/2017 4:49 PM	Python File	22 KB
Status_Board_Data	10/28/2018 1:41 PM	Microsoft Excel C...	6 KB



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# Part II: Control Rod Calibration Program

# Perturbation Theory



# Control Rod Calibration Procedure



- Four B<sub>4</sub>C control rods calibrated annually
- “Rod Pull” Method:
  - Achieve criticality at 15W with 3 control rods, range up to 1kW
  - Withdraw rod being calibrated, establish positive period
  - Linear channel timer measures time (ms) to go from 200W-800W
  - Repeat until rod fully withdrawn (then repeat for other rods)
  - Spline interpolation of data points

$$P = P_0 e^{t/T} \rightarrow T = t / \ln(P/P_0)$$

$$\beta = \frac{l^*}{\beta_{eff} T} + \sum_{i=1}^6 \frac{\beta_i}{1 + \lambda_i T}$$

# Control Rod Calibration Program



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- Python 2.7 with TkInter module  
(Same as Status Board)

Pull Number [#]	Starting Position [%]	Ending Position [%]	Rise Time [ms]	Reactor Period [1/s]	Reactivity [\$]	Integral Reactivity [\$]
1	0.0			---	---	0.0

# Control Rod Calibration Program



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OSTR Control Rod Calibration

Select Control Rod:

Plot Results

Pull Number [#]	Ending Position [%]	Rise Time [ms]	Reactor Period [1/s]	Reactivity [β]	Integral Reactivity [β]
7			---	---	1.71
1	0.0	20.0	35400.0	25.54	0.24
2	20.0	35.0	25200.0	18.18	0.29
3	35.0	55.7	16700.0	12.05	0.36
4	55.7	72.4	18450.0	13.31	0.34
5	72.4	89.0	24201.0	17.46	0.3
6	89.0	100.0	56203.0	40.54	0.18

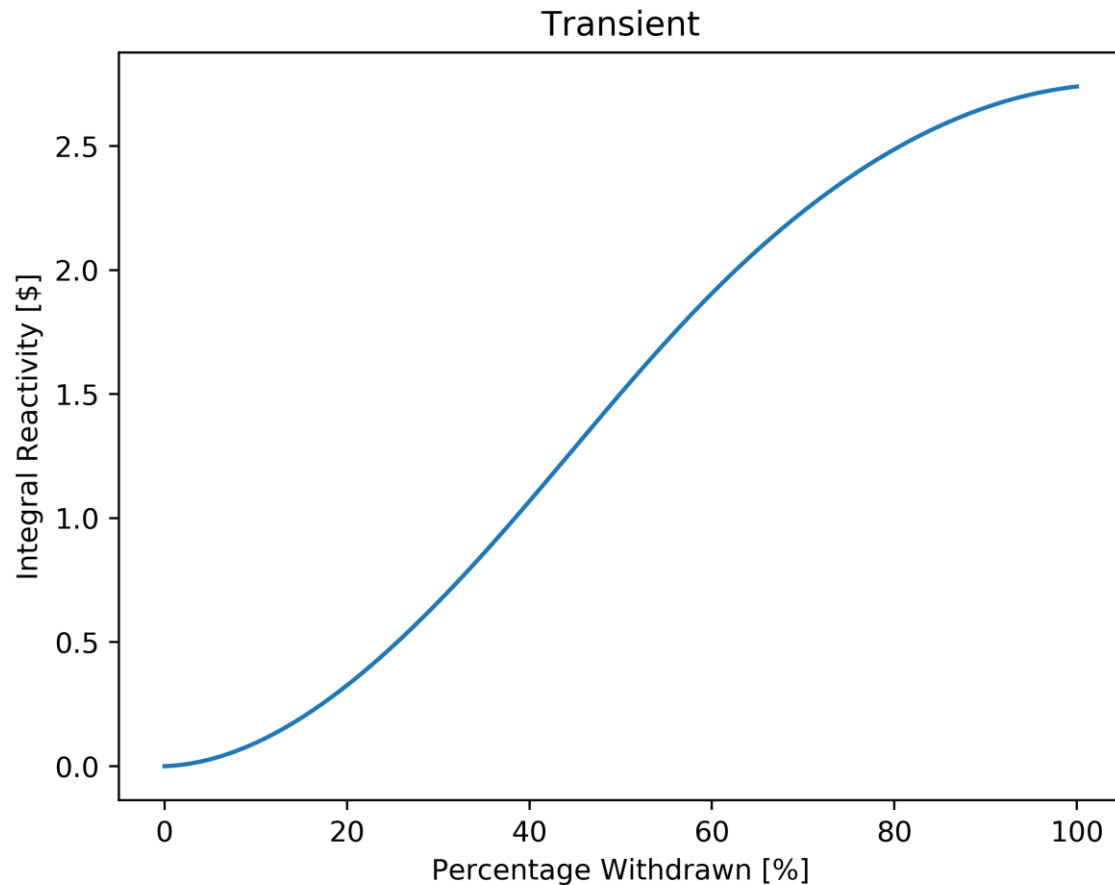
Next



# Program Output



- Integral rod worth plot
- .csv file with  $\rho/\Delta\rho$  data














	A	B
502	50.1	\$ 1.51
503	50.2	\$ 1.51
504	50.3	\$ 1.52
505	50.4	\$ 1.52
506	50.5	\$ 1.52
507	50.6	\$ 1.53
508	50.7	\$ 1.53
509	50.8	\$ 1.54
510	50.9	\$ 1.54
511	51.0	\$ 1.55
512	51.1	\$ 1.55

# Program Output



- Name of control rod / date performed

 OSTR_Rod_Cal	7/31/2018 7:57 PM	Python File	8 KB
 OSTR_Rod_Cal.spec	7/24/2017 11:37 A	SPEC File	1 KB
 Regulating Integral Rod Worth Curve	7/25/2017 2:50 PM	PNG File	169 KB
 Regulating Rod Calibration 7 25 2017	7/25/2017 2:51 PM	Microsoft Excel Co...	36 KB
 Safety Integral Rod Worth Curve	7/25/2017 2:45 PM	PNG File	181 KB
 Safety Rod Calibration 7 25 2017	7/25/2017 2:45 PM	Microsoft Excel Co...	36 KB
 setup	7/24/2017 11:28 A	Python File	1 KB
 Shim Integral Rod Worth Curve	7/25/2017 2:48 PM	PNG File	158 KB
 Shim Rod Calibration 7 25 2017	7/25/2017 2:48 PM	Microsoft Excel Co...	36 KB
 Transient Integral Rod Worth Curve	7/25/2017 2:28 PM	PNG File	161 KB
 Transient Rod Calibration 7 25 2017	7/25/2017 2:28 PM	Microsoft Excel Co...	36 KB



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**Questions? Thank you!**